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WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS

Improving water quality assessment and supply

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OVER 90 PER cent of avaiable freshwater in the Arusha region of Northern Tanzania is abstracted from groundwater aquifers. The majority of this is from regolith-hosted or alluvial hosted groundwater aquifers situated within 30 m of the surface. Historically this weathered mantle was assumed to protect groundwater from contamination and it is only recently that water quality has been monitored (Coster, 1950; Wateraid, 1991). It has been demonstrated that the biogeochemical processes influencing water quality are complex (Lahermo et al., 1991; Mjengera, 1991; Smith et al., 1996; Bowell et al., 1996).

The aim of this paper is to describe the relationships between water chemistry and microbiological activity in protolith (collected below 30m, hosted by unweathered bedrock), regolith (above 30m, water hosted in the weathered rocks and soils) and alluvial hosted groundwaters in urban (Arusha district) and rural areas (Hanang, Mbulu and Babati districts) of the Arusha region, Tanzania. An assessment is made of possible advantages and disadvantages in utilising the various groundwaters as supplies of potable water and in potential treatment options.

Topography and geology

The Arusha region in Northern Tanzania consists of volcanic highlands, part of the East African Rift (EAR) Valley, comprising of Teritiary volcanics with a central plain with isolated hills and inselbergs resting on Precambrian basement complex (Cahen and Snelling, 1984). The region is dominated by a series of steep mountains and volcanic mountain chains the highest of which are Mount Meru (4565m) and Mount Hanang (2100m). Surface water is abundant in the highlands with ephermal streams on the plains. At the base of the fault escarpment of the EAR are a series of seasonally saline, permanently saline and freshwater lakes which occur in old volcanic craters and depressions. The drainage pattern of the area flows from the highlands to the plains (south and south-east). Precipitation varies throughout the region with a maximum of 2000mm in the highland areas in the wet season to virtually no rain on the Masaai palins for 3-4 months of the year.

The central plateau and uplifted block around Hanang-Balangida are composed of Archaean synorogenic granitoids and gneisses. In the west the Nyanzian rocks occur as remanant blocks in the granitic terrain. The dominiant rock type in the area are quartz-feldspar granite-gneiss, locally rich in biotite, of Usagaran-Ubendian age.

The Teritiary to Recent volcanic rocks occur largely in the north of the region with major centres at Meru, Hanang, Ngorongoro, Ngurdoto, and Duluti. They comprise of alkali-olivine basalts, nephelinite and phonolite lava flows and volcaniclastics. Although these deposits have a noticeable effect on local ground and surface water, the effect is localized and has little effect on regional water quality (Bowell et al.1997).

Regolith development is most extensive in the basement rocks on the plateaus and can be as much as 50 m thick. In the volcanic areas, regolith development is not as great and can vary from < 1m to 30m thick. Ferralsolic soils cover most of the region although on the craters of Ngongoro, Hanang and Mt Meru, andosol, nitosol, cambisols and podzols are also present. On the plains around Arusha and Tarangerie partial and complete laterite horizons are observed. Black clay-rich soils termed "mbugas" are common on peneplain areas in the Babati and Hanang districts and are often an important source of shallow groundwater.

Groundwater aquifers are situated within fractures, faults and joints in the protolith. More commonly water is abstracted from various parts of the regolith from cavities, pores and pockets and from palaeo-alluvial and alluvial channels. This water can be accessed *via* hand dug wells and hand pumps (Coster, 1950; Wateraid, 1991; 1992).

Results and discussion

Much of the protolith groundwater is alkaline of the type Na-Ca-HCO_3 from both volcanic and basement aquifers with higher Ca, Mg, B, SiO_2 and F in the volcanic hosted aquifers with significant seasonal variations in water chemistry (Bowell et la., 1992; 1995).Sulfate, phosphate and K levels are higher in the basement protolith groundwaters, possibly as a result of mineral-water interactions with sulphates in marine sedimentary units and sulphides in metamorphosed granites. However sulphide was not analysed from any samples. Chloride levels are variable but the overall trend is that the basement protolith aquifers have slightly higher chloride levels, possibly because of a longer residence time in the aquifers related to there topographic position on the plains.

From the hydrogeochemical and microbiological data a number of potential health problems due to high concentration of various water parameters can be observed:

- High salinity from high rates of evapotranspiration with Total Dissolved Salt (TDS) levels in excess of 3000 mg/l

- High Fluoride concentration, associated with F-rich magmatic rocks with up to 600 mg/l F in thermal springs associated with volcanic centres at Kondoa and Meru.
- High concentrations of some metals in regolith groundwaters related to mineral-water reactions during tropical weathering. Concentrations range up to 36 mg/l aluminium, 20 mg/l iron, 3 mg/l manganese, and up to 1 mg/l cobalt, copper and zinc.
- Biological contamination indicated by Fecal colliform levels in excess of 250 counts in 100 ml, high nitrate (up to 180 mg/l), phosphate (up to 65 mg/l), sulphate (up to 400 mg/l) and potassium (up to 31 mg/l).

Implications for human health and water utilization

The concentration of certain water parameters can have a direct effect on human health. For example, nitrate in groundwater is considered a health risk because it may cause methaemoglobinemia in human infants, potentially a fatal syndrome as it impairs oxygen transport in the blood. An upper limit of 50 mg/l nitrate (or 11 mg/l NO_3-N) is commonly used to indicate unacceptable nitrate contamination (WHO, 1990).

Salinity

High salinity in some drinking waters is the most common health problem encountered in the Tanzanian ground waters of the Arusha region with many waters above the 500 mg/l limit in the dry season. In some waters low levels of Mg and Ca may intensify already existing Ca-Mg deficiencies although over 80 per cent of dietary Ca is obtained from diary products and proteins. However this is only a problem from acidic waters in the regolith. The highly alkaline groundwater's common in much of northern Tanzania are likely to add up to 20per cent of dietary Mg and Ca (Sharrett, 1977). In some cases the level of Mg and sulphate are sufficiently high to produce diarrhoea (Mg>50 mg/l and SO_4> 250 mg/l).

Fluorine

Fluorides are one of the few elements largely ingested through drinking water (up to 70per cent). In low concentration (1 mg/l) fluoride is extremely useful in reducing tooth decay but too high an intake leads to painful skeleton deformations termed fluorosis (Moller, 1982; Mosha and Moshi, 1982). This condition occurs in many areas where recent alkaline volcanic activity has occurred, such as in parts of India, Sri Lanka, Bangledesh, China as well as East Africa (Mills, 1984; Sharper, 1984; Lahermo et al., 1991; Davies and Davies, 1993; Dissanayake, 1996). For many of the ground waters in the Arusha region fluoride levels are considerable elevated above the 1.7 mg/l limit globally and even the local drinking water limit of 4 mg/l. In order to reduce F levels, defluoridation treatment is used (Mjengera, 1991).

Metals

For most metals, other than Cr, drinking water supplies a very small component of daily requirements with the major nutritional sources being from meat. However the levels of several metals, including Cr, do exist at levels in excess of the maximum admissible level. Iron discoloration of water and associated "metallic taste" occur where concentrations exceed 1 mg/l and are due to insoluble ferric salts flocculated in the ground water. This is only really a problem where water is abstracted from the regolith and has been identified as a common problem in the tropics (Wateraid, 1991). Iron is not only present through geochemical processes in the groundwater but may also be produced by corrosion during treatment of the water . Similarly manganese produces discoloration and an unpleasant taste above 0.15 mg/l (WHO, 1984). As with iron increased concentrations of manganese in groundwater is largely in response to acidification. Precipitation of both metals in the aquifer or supply wells will reduce flow and promote biological activity and microbial growth, which may explain the apparent association between these metals and biota activity in tropical groundwater's (McFarlane and Bowen, 1992). Of increased concern in recent years has been the level of aluminium in groundwater's and apparent occurrence of Dialysis encephalopathy caused by aluminium accumulation in the cytoplasm of neurons (Connery, 1990). However aluminium does not cause the disease but will aggravate it. Above 0.1 mg/l Al water may also be discoloured and a maximum permissible limit of 0.2 mg/l is recommended. As with iron and manganese aluminium mobility in groundwater is largely confined to the mildly acidic regolith groundwater's but in northern Tanzania all the high fluoride groundwater's showed aluminium concentrations well above maximum permissible levels. However, recent work by Smith et al. (1996) has shown that only a small fraction of aluminium in groundwater is bioavailable and even at a level of 1.5 mg/l, drinking water supplies only 4per cent of the total daily aluminium intake.

Biological contamination

The level of phosphate in most waters is too low for this to contribute to diet except in the high nitrate waters which are unsuitable because of the health risk from nitrate. Other high phosphate waters are also used, abstracted from shallow wells in the regolith but the high nitrite and faecal coliform counts are indicators of high biological activity and should also be considered unsuitable.

Corrosion and encrustation

Low carbon steel is more susceptible than other materials to corrosion and is a common source of well failure. Even slight corrosion can have a marked effect on the chemistry of the resulting water particularly iron levels. Factors which are considered important in recognising this corrosion potential low pH, high dissolved oxygen (>2 mg/l), Total Dissolved Solids/Salts (> 1000 mg/l); CO_2 (> 50 mg/l); and chloride (> 500 mg/l).

The presence of two or more of these conditions greatly intensifies the potential corrosion. By examining the ground water chemistry from northern Tanzania the only corrosive parameter that is of any real concern is high Total Dissolved Solids. Seasonally many of the groundwater's exceed this and indicate that groundwater's are potentially corrosive. To avoid electrolytic corrosion, metal well screens should be made of a single corrosion-resistant metal. Metal pipes need to be constructed of durable material such as Type 304 stainless steel or better. An additional problem in the alkaline groundwater's is that of encrustation of minerals on pipe surfaces or in pores. Indicators of encrustation potential include high: pH pH (> 7.5); Carbonate hardness (> 300 mg/l) Iron (> 0.5 mg/l) and Manganese (>0.2 mg/l) in oxidising alkaline waters. To assist in predicting encrustation and corrosion potential of the waters the Langelier and Ryznar Stability Indices can be used. Taking the minimum and maximum value for protolith and regolith groundwater it can be observed that in the dry season many of the waters are corrosive and corrosive nature could explain why some drinking water samples analysed from Arusha contain higher levels of Fe, Mn and Co. In the spring waters from Jekukmia and Manyara the indices would suggest that encrustation is occurring.

Conclusions

High concentrations of several components adversely affect groundwater quality in northern Tanzania. This has important implications for use of available water. The major problems of water quality in the region can be divided into four groups:

- High salinity from high rates of evapotranspiration and high solute concentrations in groundwater's from active chemical weathering. Total Dissolved Salt (TDS) levels in excess of 3000 mg/l have been recorded in some groundwater's.
- High Fluoride concentration, associated with F-rich magmatic rocks with up to 600 mg/l F in thermal springs and also assisted by high rates of evapotranspiration.
- High concentrations of some metals in regolith groundwater's related to mineral-water reactions during tropical weathering. Aluminium concentrations are also high in high fluoride waters due to the stability of Al-F complexes. Concentrations range up to 36 mg/l aluminium, 20 mg/l iron, 3 mg/l manganese, and up to 1 mg/l cobalt, copper and zinc.
- Biological contamination indicated by Faecal coliform levels in excess of 250 counts in 100 ml, high nitrate (up to 180 mg/l), phosphate (up to 65 mg/l), sulphate (up to 400 mg/l) and potassium (up to 31 mg/l). This occurs mainly in shallow regolith groundwater's close to the surface contaminated by high levels of organic-N in the soils, agriculture and poor sanitation.

These problems result in poor water quality requiring additional water treatment prior to safe consumption. This study highlights the need for adequate monitoring and evaluation of water quality prior to utilisation and an understanding of the biogeochemical processes which effect groundwater quality in tropical terrain's.

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